RESEARCH HIGHLIGHT

December 2011 Technical Series 11-103

Earth Tube Ventilation Systems—Applicability in the Canadian Climate

INTRODUCTION

Earth tubes, also called earth-to-air heat exchangers (EAHX), ground-coupled heat exchangers, or earth channels, are long plastic or concrete pipes that are laid underground and are connected to the air intake of buildings. Their purpose is to make use of the fairly constant temperature of the ground to provide some pre-conditioning of the ventilation air – either pre-heating in the winter or pre-cooling in the summer. EAHX systems received some attention in the late 70's and early 80's but have not been widely adopted.

The current push towards a wider use of "green" technologies has generated interest in the concept of earth tubes. The systems are promoted as a simple and effective way to reduce the amount of greenhouse gases associated with the operation of buildings. However, there is a lack of information on the effectiveness of earth tubes with respect to potential and quantifiable energy savings. Additionally, information is lacking concerning the impacts on the indoor air quality (IAQ). For these reasons Canada Mortgage and Housing Corporation (CMHC) initiated a study in 2010 to research the availability of valid information on earth tube ventilation systems and their applicability in the Canadian climate, upon which builders and consumers can make informed decisions. This Research Highlight reports the results of this study.

RESEARCH OBJECTIVES

The focus of the study was residential EAHX systems. The objectives were:

1. To research information on actual, monitored performance of existing residential earth tube systems in Canadian climate conditions, including: energy savings, indoor air quality, design and construction methods, and costs.
2. To synthesize the research information to formulate broad conclusions regarding the performance of earth tube systems in Canada.

METHODOLOGY

The research comprised several components:

- A literature and internet search was conducted. This research focused on papers and publications that document the use, performance and air quality of actual EAHXs. The search was conducted both in English and French. It was complemented by postings on electronic bulletin boards, email exchanges or phone conversations with scientists, designers and installers, and manufacturers involved in this field. Over 45 publications were analyzed and summarized.

Canada

CMHC SCHL
HOME TO CANADIANS

- Existing Canadian EAHX systems were researched, and actual, monitored performance data were sought. Close to 30 residential systems in existence or being built were identified, as well as nearly 10 more in the commercial sector. Knowledge about the systems was gained through discussions and email exchanges with their designers or operators.
- Finally, the information gathered from these various sources was synthesized to identify trends in the state of knowledge of energy performance, indoor air quality (IAQ) implications, design and construction features and system costs, etc.; general conclusions regarding the performance of earth tube systems, their applicability, and their suitability, were drawn.

It should be noted that the focus of the study was residential systems in Canada. However it soon became quite clear that existing Canadian systems would not provide enough information to be able to draw conclusions because there are very few, and none have been rigorously monitored. The study was therefore expanded to systems outside Canada, for example in the USA but more notably in Europe where earth tubes are used more frequently. The study was also expanded to include some commercial / institutional buildings; primarily because very little monitoring has been done for residential EAHXs whereas data exists for commercial buildings in greater quantity and quality. Commercial EAHXs tend to be much larger, more sophisticated, and meet different load patterns than residential systems; however some of the lessons that can be learned from their operation are also applicable to residential systems.

RESULTS

Earth tubes have been widely deployed in some parts of Europe, particularly Germany, France, and Switzerland, with hundreds if not thousands of installed systems. Despite the number of residential EAHXs in service in Europe, there is a lack of comprehensive data about the actual performance of residential EAHX systems. With respect to the coefficient of performance (COP) and cooling or heating capacity of EAHX systems, the literature suggests that they vary with the temperature difference between ambient air and the ground: the capacity and COP will appear very high when the difference is greater and very low when the temperatures are close to each other. The numbers will appear radically different depending on when they are measured or over what period they are averaged. Seasonal COPs are frequently reported in the range 3 to 4. The literature shows that a typical residential EAHX will have an average cooling power around 1.5 kW with peak cooling power around 4 kW, although this will of course depend on local climatic and soil conditions.

Only a limited number of systems have been found in North America. A few are manufactured, but most are custom-made. Users report mixed results. Some users express general satisfaction with the systems, but objective performance indicators are lacking. Other users report that their systems do not always work as expected. In short, it is hard to draw general conclusions from the research conducted on the current stock of EAHX systems installed in the USA or Canada.

The literature suggests that a possible reason why EAHXs are more common in Europe is that they may offer sufficient cooling to enable the house to remain comfortable through heat spells, thereby reducing the need for mechanical air-conditioning. The situation will not necessarily be similar in Canada since EAHXs do not seem to have significant dehumidification potential - a capability that is desirable for a number of Canadian locations.

Typical performance

Monitored results gathered from the literature show that, under the right circumstances, earth tubes can provide some benefits. These benefits are observed on a seasonal basis (i.e. average temperature of air delivered by the system varies less than ambient temperature from one season to the next) but also on a daily basis (temperature during the day is relatively constant). On average, air delivered by the EAHX is warmer than outside air in winter, and cooler in summer. The daily amplitude of temperature is also much reduced, and the EAHX appears very effective at clipping temperature peaks during hot days in summer.

Experience with existing systems, both in Europe and in North America, shows numerous potential areas of concern that one should pay attention to when considering the use of EAHXs for residential systems.

A deceptive simplicity

Despite the apparent simplicity of EAHX systems, the literature reveals that they are actually very complex systems. They need a proper choice of materials and careful construction techniques to avoid potential infiltration of water and radon, mold problems and accumulation of condensates. They involve both sensible and latent heat transfer. They require sophisticated controls and may need to be bypassed during some periods. They have a thermal memory: because of accumulation of heat in the ground, the amount of energy extracted or evacuated during a given hour depends on how much was extracted or evacuated in previous hours or days. And finally, they interact with the rest of the house to which they are connected.

Air quality concerns

The literature contains conflicting reports about air quality in EAHXs. Although few publications exist on the subject, some authors report that air quality does not seem to be a problem, as long as the system is properly designed, installed, operated and maintained. According to the literature, properly conceived system will include smooth tubes (possibly with anti-microbial coating), a sloping design collecting and evacuating condensates at a low point, tight joints, and proper filters at the air intake. Air will not be left stagnant in the tubes, and the filters will be replaced regularly. Under such conditions, some authors report that air of good quality is delivered to the dwelling. However, this may be attributable to filtration more than the fact that air is being drawn through an EAHX.

Nevertheless, the potential for condensation on the surface of the tubes in summer, where warm, humid air is drawn through tubes in contact with cool earth, is a concern to some authors, as it may be conducive to the growth of mold and bacteria. Some proponents of the PassivHaus standard have reported anecdotal evidence of air quality problems with earth tubes in northern Europe, especially in Scandinavia, but not in Central Europe, though they aren't sure why they don't have these problems in Central Europe. Problems have also been reported with systems in Sweden. This area seems to be incompletely understood so caution should be exercised, especially since places where problems have been reported (Scandinavia) have climates very similar to some parts of Canada.

It should be noted that some systems address the condensation and IAQ concerns by not having the ventilation air pass through an earth tube to temper the ventilation air.. The alternative approach uses an underground glycol or brine loop with a heat exchanger located at the entrance of the heat recovery unit. Other than air quality concerns, these systems share many of the characteristics of air-based systems. The benefits of these systems have not been demonstrated with monitored data in Canada.

Controls

The literature reviewed strongly suggests that operating EAHXs 24/7, year round, is not beneficial. There are numerous reports of EAHXs delivering warm air when cold air is needed, or vice versa. For example in the middle of summer it may be beneficial to stop the EAHX at night and draw air directly from the outside if it is cooler. The problem is also prevalent in Fall and Spring seasons. For example in spring, since the temperature of the ground lags behind ambient temperature, the EAHX tends to cool, not warm, the air it delivers to the house. The literature indicates that EAHXs working under such adverse conditions can provide a very significant 'negative' contribution to the overall heating or cooling needs of the building. Several solutions have been proposed, such as manual controls (seasonal bypass or manually operable switch), or automated bypasses (either total or partial, to avoid stagnant air sitting in the tubes for extended periods of time). The literature suggests that the latter should be considered seriously in any installation, but this adds complexities to a system that is initially being used for its simplicity.

Long term temperature imbalance in the ground

The long-term reduction in the heating/cooling capacity of the ground is often not properly considered. There is some evidence in the literature that the heating or cooling capacity of the soil becomes much diminished after some time (depending upon numerous factors such as thermal properties of the ground, flow rate in the EAHX, etc.), and that the heating or cooling capacity measured over a month will be much lower than that measured over one day. This effect happens both in winter and in summer - for example

operating a EAHX in a very cold climate for weeks in winter with sub-zero temperatures may actually freeze the ground around some parts of the EAHX; and in summer, the EAHX may prove effective in the first few days of a heat wave but not if the heat wave persists.

Note also that some EAHX systems have been reportedly located around the foundations of the residence or under the slab, the idea being that the system can reclaim some of the heat losses of the house in winter. It is not obvious that this approach is actually beneficial, because it actually exposes the slab or the foundations to colder temperatures. In at least one example from the literature, it has been shown to have a globally negative influence on the thermal balance of the building.

Interaction with the heat recovery ventilator (HRV)

The literature shows that strictly from an energy point of view, there is very strong evidence that combining an EAHX and a HRV provides little benefit in heating mode. Both devices are trying to raise the temperature of the incoming air; but the temperature rise caused by the EAHX makes the HRV work less efficiently, so the combined energy gain is much less than the sum of the gains of each system working independently.

This is also confirmed by several experimental studies which have shown that when an HRV is present, the advantage of combining it with an EAHX is minimal from an energy point of view.

One of the often- cited benefits of the EAHX in Europe is to provide frost protection to the HRV; however, in North America, HRVs have defrost cycles that achieve the same result at no additional cost since they are standard in all units.

Economics

With system costs typically reported in the range of $2,000 to $3,000 or even much more, payback is often reported to be long - 10 to 20 years--as long as excavation costs are kept to a minimum. Based on interviews, it appears that excavation expenses are one of the big drivers of the overall cost of the system.

Other factors which reduce the economic appeal of EAHXs are the fact that the systems tend to work seasonally, that they require sophisticated controls or risk heating and cooling when they should not, and that their functionality overlaps that of the HRV in heating mode. It should also be noted that EAHX systems can only be used with tight envelopes: in leaky houses when infiltration is high, the earth tubes provide additional fresh air that may not be needed.

CONCLUSION

This study has shown, through a literature search and interviews with researchers, owners and operators, that EAHXs may have benefits when used under the right conditions and in the right climate, but also that they are very subtle systems which require careful design and operation to be successful. The literature shows that an improperly designed system will not work as expected, or result in poor air quality, etc. leading to disenchantment with the system and in many cases decommissioning: it is often very difficult to fix EAHXs once the trenches are back-filled.

The literature also shows that controls, air quality, and thermal memory of the ground are but three of the areas to pay close attention to when considering an EAHX. It also demonstrates that an EAHX can be redundant when used in conjunction with heat recovery ventilators (HRV), and that the economics are rarely favourable.

Manufactured systems are available that offer improvements over building one's own EAHX and avoid some of the many pitfalls that can plague poor designs.

One clear result of the study is that there is no 'one size fits all' approach to the use, design, installation and operation of EAHXs. Each design will be a particular case based on local climatic conditions, soil properties, and house characteristics. There exist many books, manuals, papers, and web sites, which can be helpful in researching and designing the system. However, these sources of information may not necessarily relate to residential applications, Canadian climatic conditions and experience.

The main finding of this study is that the performance of EAHXs in most of Canada's climatic conditions has not yet been demonstrated through validated rigorous energy and indoor air quality monitoring. Until such data can be obtained, the findings from this project need to be carefully evaluated prior to undertaking any such installation.

IMPLICATIONS FOR THE HOUSING INDUSTRY

The absence of comprehensive research, testing and analysis on the performance of EAHX systems makes it difficult for prospective users to assess whether or not EAHX systems are appropriate for any given installation. However, pre-manufactured EAHX systems that are purposely designed for specific applications, rather than custom-made ones, may offer builders and homeowners more assurance that benefits will be realized and potential problems avoided.

CMHC Project Manager: Ken Ruest

Consultant: Didier Thevenard, Numerical Logics Inc.

Housing Research at CMHC

Under Part IX of the ***National Housing Act***, the Government of Canada provides funds to CMHC to conduct research into the social, economic and technical aspects of housing and related fields, and to undertake the publishing and distribution of the results of this research.

This Research Highlight is one of a series intended to inform you of the nature and scope of CMHC's research.

To find more ***Research Highlights*** plus a wide variety of information products, visit our website at

www.cmhc.ca

or contact:

Canada Mortgage and Housing Corporation
700 Montreal Road
Ottawa, Ontario
K1A 0P7

Phone: 1-800-668-2642
Fax: 1-800-245-9274

Printed in Canada
Produced by CMHC 30-12-11

67558